Vol. IX. *September, 1905.* *No. 4*

BIOLOGICAL BULLETIN

THE ANATOMY OF THE EYES AND NEURAL GLANDS IN THE AGGREGATED FORMS OF CYCLOSALPA DOLICHOSOMA-VIRGULA AND SALPA PUNCTATA.[1]

MAYNARD M. METCALF AND MARY E. G. LENTZ JOHNSON, M.A.

(WITH PLATES VII., VIII. AND IX.)

The eyes of the solitary salpas of the several species show but little diversity. All are in the form of a horseshoe above the ganglion, the ends of the horseshoe pointing forward. In *Iasis cordiformis-zonaria* the ends of the horseshoe diverge, pointing outward and upward at an angle of about 45°. In *Salpa runcinata-fusiformis* there are masses of somewhat irregular rod-cells in the dorsal part of the ganglion, in front of the eye. With these exceptions the differences in the eyes of the solitary forms of the different species are too minute for verbal description.

In the aggregated forms, on the other hand, the diversity between the eyes is very great. Each species has its own characteristic and distinctive form of eye and the histological differences

[1] This study of the eyes and neural glands of two species of *Salpidæ* was accepted in June, 1903, by the Woman's College of Baltimore, in partial discharge of the requirements for the degree Master of Arts at that time conferred upon Miss Mary E. G. Lentz. Its publication has been delayed until I could receive and study additional material of these and other species of Salpa in the hope of getting conclusive evidence upon disputed points of innervation. I obtained from Naples material of three species of Salpa preserved some in half strength glycerine and some in chloral hydrate, and endeavored to study the innervation of the eye by the use of dissociation media, especially Haller's acetic acid mixture, but the results obtained are not sufficiently conclusive to warrant publication.

MAYNARD M. METCALF,
Professor of Biology, The Woman's College of Baltim re.

are great. In addition to the large dorsal eye some species have smaller eyes in the ganglion, and the number, position and character of these smaller eyes vary with the species. It is, therefore, important that we have recorded descriptions of the anatomy of the eyes in the chain individuals of all species. Especially is this true since suggestions as to relationship, so readily received from the study of the eyes, appear to be trustworthy.

The neural glands of the chain forms of different species may also be very diverse, making it desirable to have descriptions of their anatomy in all species.

In the present paper the anatomy of the eyes and of the neural glands will be described for the chain forms of two species whose eyes have not before been studied—*Clycosalpa dolichosoma-virgula* and *Salpa punctata*.

The other salpas the anatomy of whose eyes has been studied are:

Cyclosalpa pinnata, solitary and chain forms (by Göppert and Metcalf).

C. chamissonis, chain form (by Metcalf).

Salpa africana-maxima, solitary and chain forms (by Göppert and Metcalf).

S. runcinata-fusiformis, solitary and chain forms (by Göppert and Metcalf).

S. cylindrica, solitary and chain forms (by Metcalf).

Iasis hexagona, solitary and chain forms (by Metcalf).

I. costata-tilesii, solitary and chain forms (by Metcalf).

I. cordiformis-zonaria, solitary and chain forms (by Metcalf).

Pegea scutigera-confederata, solitary and chain forms (by Göppert and Metcalf).

P. scutigera-confederata var. *bicaudata*, chain form (by Metcalf).

Thalia democratica-mucronata, solitary and chain forms (by Göppert and Metcalf).

The anatomy of the neural glands has been described by Metcalf for the chain and solitary forms of the species mentioned in the foregoing list, except that the gland has not been described for the solitary *Pegea scutigera-confederata* var. *bicaudata*. It is probable that *bicaudata* is a variety of the chain form only and that its solitary form resembles that of *scutigera-confederata*.

The development of the eyes and neural glands has been described by Metcalf for *Cyclosalpa pinnata*, chain and solitary forms.

CYCLOSALPA DOLICHOSOMA-VIRGULA, chain form.

The condition of the eye in this species is of interest because it forms the third link in a series of three conditions bridging over the gap between the *Cyclosalpæ* and the true *Salpæ*. The structure of its neural glands is not unique.

The brain of *Cyclosalpa dolichosoma-virgula* is a ganglion of almost spherical shape (Fig. 1). Two outgrowths from the ventral surface, one on either side of the mid-line, extend to the neural glands whose position is ventro-lateral to the ganglion. These glands, with their long lateral ducts, are partially shown in Fig. 1 (*h*, gland; *d*, duct). On the postero-dorsal surface of the ganglion is a slight protuberance (Fig. 5, *pr*). All the nerves, with the exception of a single pair, spring from the equatorial zone of the ganglion (Fig. 1). One pair arises from the ventral outgrowths. The nerves are probably constant in number for the species — forty-eight.

The large ovoid eye (Fig. 1) projects anteriorly from the posterior end of the dorsal surface of the ganglion, and the long axis of the eye makes with this surface an angle of about 30° (Fig. 5). The eye points about 40° from the mid-line of the body, to the right or left, according as the animal lies to the right or left in the chain. One third of the eye, approximately, extends beyond the anteriormost edge of the ganglion.

There is a deep invagination of the ectoderm into the narrow space between the eye and the ganglion, and a less abrupt invagination just posterior to the ganglion (Fig. 5). In the ectodermal chamber formed between these two invaginations lies the eye, which presses closely against the ectoderm only at its tip. Blood sinuses (Fig. 1, *bl*) which surround the ganglion are continuous with this optic chamber (Fig. 5, *oc*).

The ganglion has the usual fibrous core, and a peripheral cellular layer (Fig. 5), which extends inward about one seventh of the diameter. The postero-dorsal protuberance (Fig. 5, *pr*), is made up of ordinary ganglionic cells. Large nerve cells (Fig. 5, *nc*), lie in the equatorial zone from which the nerves arise.

These large cells lie among the smaller ganglionic cells of the peripheral layer. A large bundle of nerve fibers, arising in the fibrous core of the ganglion, passes through the peripheral cellular layer, just anterior to the protuberance on the posterior surface, and enters the eye at its posterior end, forming the optic nerve (Fig. 5, *on*). Fibers ramify also among the cells of the postero-dorsal protuberance (Fig. 5, *pr*).

Four kinds of cells are found in the large eye, and one of these, so far as known, is peculiar to this species. The pigment cells and rod-cells resemble the characteristic cells found in the well-developed eyes throughout the genus. The pigment cells cover the dorsal surface of the eye from near the tip to slightly beyond the middle (Fig. 1 and Fig. 5, *dp*). They then extend around the lateral surfaces in posteriorly-directed broad bands, uniting on the ventral surface to form a pigment layer which extends from beyond the middle of the eye to the base (Fig. 5, *vp*). The position of the dorsal and ventral pigment is also shown in cross sections (Fig. 7, *dp*; Fig. 9, *vp*). A cross section through the middle of the eye (Fig. 8), shows the complete enwrapping of this portion of the eye by pigment. The pigment cells lie outside the optic membrane (Fig. 5, *oz*), which is a continuation of the ganglionic membrane. They are therefore probably mesodermal.

The rod-cells are elongated cells with large nuclei (Fig. 5, *dr* and *vr*). They have thick-walled basal ends and thin-walled tips. In the anterior and posterior regions of the eye the thick-walled ends of the rod-cells are toward the pigment (Figs. 5, 7 and 9). In the center of the eye, where the pigment forms a continuous enveloping layer, the thick-walled inner ends of the rod-cells have a somewhat confused arrangement, while their thin-walled tips point toward the pigment cells (Figs. 5 and 8).

The third kind of cells present in the eye are similar to the ordinary cells of the ganglion, having nuclei of about the same size. These cells, which have been called intermediate cells, lie between the thick-walled ends of the anterior and posterior rod-cells and the pigment cells (Fig. 5, *i* and *i'*; Fig. 7, *i*; Fig. 9, *i'*). Intermediate cells are not present in all species. In the chain forms of *Cyclosalpa pinnata* and *Pegea scutigera-confederata* the rod-cells abut directly on the pigment layers.

The large optic nerve, when it enters the eye, passes directly above the thin-walled ends of the rod-cells in the posterior portion of the eye (Fig. 5; Fig. 9, *on*). The nerve can easily be traced as far as the middle of the eye, but the course of the fibers beyond that point could not be satisfactorily determined. In sections through the tip of the eye, the nerve fibers seem to appear ventral to the rod-cells (Fig. 5), and it seems probable that they enter these cells at their thin-walled ends; but the shrinking of the protoplasm from the tips of the rod-cells, apparently due to the action of the preserving fluids, makes the rod-cell walls more clearly visible, so that it is very difficult to distinguish between these cell boundaries and probable innervating fibers. Sufficient evidence was not obtained to warrant a categoric denial of Göppert's assertion that the rod-cells in the anterior portion of the eye, in the chain forms, receive their fibers at their thick-walled ends, though the indications are all against this belief. To conclusively decide this disputed point of innervation, attempts were made at macerating preserved material, but without success. Any one able to obtain fresh specimens could probably determine readily by maceration the manner of innervation. Best suited for this purpose are the following species, in which the rod-cells are well-developed: *Cyclosalpa pinnata*, *Cyclosalpa chamissonis*, *Cyclosalpa dolichosma-virgula*, *Salpa runcinata-fusiformis*, *Salpa africana-maxima*, *Salpa cylindrica*, *Thalia democratica-mucronata*, *Salpa punctata*.

The fourth kind of cells, found in the eye of the chain form of *Cyclosalpa dolichosoma-virgula*, are those which have been mentioned as perhaps peculiar to this species. They lie in a single group, which is partially imbedded among the pigment cells of the mid-dorsal region (Fig. 5, *q*; Fig. 8, *q*; enlarged, Fig. 10, *q*). These cells are spindle-shaped, and have nuclei about the size of the intermediate-cell nuclei. They are inclined at an angle of about 45° to the long axis of the eye (Fig. 10), and they are separated from the posterior rod-cells by the optic nerve fibers. The anteriormost cells of the group are wholly surrounded by pigment (Fig. 8, *q*). There seems to be some indication that these spindle-shaped cells receive at their posterior ends innervating fibers from the optic nerve. A probable homol-

ogy of this group of cells with certain portions of the eye of *Cyclosalpa pinnata* and *Cyclosalpa chamissonis* will later be discussed.

Small groups of apparent rod-cells are found in the peripheral cellular layer of the ganglion, (Fig. 5, *ey*, *ey'*, *ey''*). They may perhaps be called small eyes, because they are made up of cells with thick-walled basal ends, similar to the rod-cells of the large eye. An enlarged drawing of one of these groups is shown in Fig. 11. The cells of these small eyes are not elongated as are the rod-cells of the large eye, and their nuclei are the same size as those of the ordinary ganglionic cells. More or less similar smaller eyes occur in the ganglia of the chain forms of *Cyclosalpa pinnata*, *C. chamissonis*, *Salpa cylindrica*, *S. runcinata-fusiformis*, *Iasis hexagona*, *I. costa-tilesii*, *Pegea scutigera-confederata* and *Thalia democratica-micronata*. Compare Fig. 18, Plate IX., which shows their position and appearance in *Cyclosalpa pinnata*.

There is no pigment present in these small eyes of any species described except *Salpa costata-tilesii*. Göppert assumes that these eyes are functional optic organs, but the absence of pigment makes the correctness of this assumption doubtful.

The small groups of rod cells which occur in the ganglion of *Cyclosalpa dolichosoma-virgula* vary in number and position, but all have about the same structure. Their cells are about the same size as the ordinary peripheral cells of the ganglion and seem to be developed from these merely by the formation of the peculiar outer glassy layer indicated in the figures (Plate VIII., Figs. 5 and 11) by the heavy black lines. The glassy outer portion of one of these cells resembles in histological character the glassy outer layer, which we have called the thickened cell-wall, seen at one end of any rod-cell of the larger eye, but the cells are of quite different shape, being spheroidal, or irregularly polyhedral, instead of cylindrical. There seems to be a general tendency in the chain forms of the different species of *Salipidæ* to form from the smaller cells of the ganglion such groups of imperfect rod-cells.

Each of the two latero-ventral outgrowths which push out from the ganglion toward the glands consists of cells of two sizes.

The ordinary ganglionic cells form that portion next to the ganglion (Fig. 6, *b*). A distinct though thin membrane then intervenes (Fig. 6, *gz*), separating the small-celled portion from a large-celled area (Fig. 6, *b'*), which extends to the wall of the gland (Fig. 6, *gw*), and is separated from the gland by a thick membrane (Fig. 6, *hz*). The thin membrane, which intervenes between the small and large cells of the outgrowths is continuous with the delicate membrane that surrounds the ganglion. The neural glands and their lateral ducts have walls made up of a single layer of cells, except that the wall of that side of each gland which lies next to the ganglionic outgrowth, is composed of several layers of cells (Fig. 6, *gw*). These conditions are very similar to those described for *Cyclosalpa pinnata.*

Salpa Punctata.

The ganglion of the chain form of *Salpa punctata* (Fig. 12) differs in shape from the nearly spherical ganglion of *Cyclosalpa dolichosoma-virgula.* Its dorso-ventral axis is about one and one half times the length of its anterior-posterior and transverse axes. Twenty-seven nerves were counted (Fig. 2). As in *Cyclosalpa dolichosoma-virgula*, they all arise from the equatorial zone of the ganglion, with the exception of a single pair from the ventral outgrowths. The average thickness of the peripheral cellular layer (Fig. 12), is about one twelfth of the ganglion's mean diameter.

In a dorsal position, just beneath the ganglionic membrane, is a double layer of rod-cells, with the thickened ends of the cells of one layer abutting upon the thickened ends of those of the other layer (Fig. 12, *ex*). These cells are not as elongated as the rod-cells of the large eye, but their bulk is about the same and their nuclei are about the same size. There are no scattered groups of small rod-cells in the peripheral cellular layer of the ganglion of *Salpa punctata*, such as have been described for *Cyclosalpa dolichosoma-virgula.* This group of rod-cells in the dorsal part of the ganglion of *Salpa punctata* probably belongs to the same category as the small eyes found in the ganglia of many species. The presence of many sorts of these small groups of rod-cells in different positions in different species renders homologies between them doubtful.

The large eye projects from the antero-dorsal face of the ganglion, and therefore lies almost wholly anterior to the ganglion. Its projection to the right or left of the mid-line of the body is slightly less than that of the eye of *Cyclosalpa dolichosoma-virgula*. The eye is relatively short, and tapers but slightly toward the tip. The dorsal pigment layer extends more than half way down over the tip (Figs. 12 and 13, *dp*), thus enveloping the dorsal half of the anterior portion of the eye in a hood of pigment. The lateral posteriorly-directed pigment bands (Fig. 15, *lp*), meet at the postero-ventral angle of the eye to form the ventral pigment surface, which is of less extent than the dorsal (Fig. 12, *vp*). Slightly posterior to the middle of the eye the dorsal pigment dips down forming a pigment curtain (Fig. 12, *pc*), which extends nearly half way through the eye, and is laterally continuous with the lateral pigment layers (Fig. 14). This pigment curtain is slightly dome-shaped with the apex of the dome toward the anterior. Fig. 14 shows a section through the pigment curtain just posterior to its apex.

The rod-cells have the same general arrangement as in *Cyclosalpa dolichosoma-virgula*, but in *Salpa punctata* those pointing ventrally (Fig. 12, *vr*) exceed in number those pointing dorsally (Fig. 12, *dr*). This corresponds to the fact already mentioned that the greater amount of pigment is on the dorsal surface. In the middle of the eye, where it is entirely enwrapped by pigment, the rod-cells point both dorsally and ventrally, with their thick-walled ends central. None point laterally, as in *Cyclosalpa dolichosoma-virgula* (compare Fig. 8, *lr*). The optic nerve enters the eye above the thin-walled tips of the posterior rod-cells (Fig. 12, *on*), and the innervation is believed to be the same as that of *Cyclosalpa dolichosoma-virgula*.

A large group of intermediate cells lies between the dorsal pigment and the ventrally-directed rod-cells (Fig. 12, *i*). A smaller group lies between the ventral pigment and the few dorsally-directed rod-cells (Fig. 12, *i'*). In *Cyclosalpa dolichosoma-virgula* the intermediate cells are confined to those two regions, but in the *Salpa punctata* the intermediate cells extend also beneath the lateral pigment layers. The position of the lateral intermediate cells in *Salpa punctata* is the same as that of the

laterally-directed rod-cells of *Cyclosalpa dolichosoma-virgula* (compare Fig. 8, *lr*), and these cells in the two species are probably homologous, the rod-cells in *Cyclosalpa dolichosoma-virgula* having developed from intermediate cells. A few intermediate cells lie posterior to the dorsal pigment curtain (Fig. 12, *q'*). The group of spindle-shaped cells in the eye of *Cyclosalpa dolichosoma-virgula* occupies a similar position (compare Fig. 5, *q*).

The ectoderm (Fig. 12, *os*), closely covers the entire eye and dorsal surface of the ganglion, except at the postero-dorsal angle of the ganglion. A membrane (Fig. 12, *z*), continuous with the ganglionic membrane, meets the ectoderm posterior to the ganglion, shutting off a small chamber (Fig. 12, *oc*), which is homologous with the posterior portion of the optic chamber of other species, such as *Cyclosalpa dolichosoma-virgula.* The limiting membrane of the optic chamber (Fig. 12, *z*), described for *Salpa punctata* is not found in *Cyclosalpa dolichosoma-virgula.* It is present in many other species, and its absence in *Cyclosalpa dolichosoma-virgula* is exceptional.

The ectoderm, after covering the eye and ganglion, turns abruptly dorsalward, so that the eye and ganglion lie just under an ectodermal invagination. This invagination thus forms a supra-neural ectodermal chamber which is filled by an unusually dense portion of the tunic (Fig. 12, *sc*). It has a somewhat triangular dorsal opening to the exterior. The supra-neural ectodermal chamber in *Salpa punctata* probably serves for the eye and ganglion a similar protective purpose to that of the large optic chamber of *Cyclosalpa dolichosoma-virgula.* A similar ectodermal invagination is found above the ganglion of the immature *Salpa runcinata-fusiformis,* chain form.

The latero-ventral outgrowths from the ganglion to the neural glands are similar in structure to those of *Cyclosalpa dolichosoma-virgula,* but smaller. The wall and duct of each gland are composed of a single layer of cells. That portion of the wall next to the ganglion is thickened by the elongation of the cells but these cells even here form a single layer. This is unlike the condition found in *Cyclosalpa dolichosoma-virgula,* in which the thickening of the gland wall next to the ganglion is caused by the presence of several layers of cells. The gland ducts of

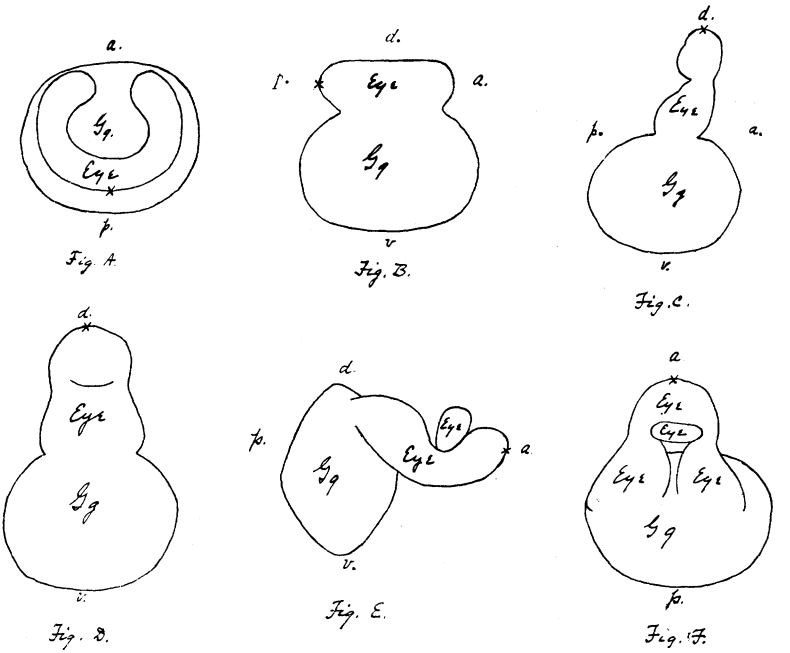
Salpa punctata are very broad and flattened, and show in cross-section a slit-like lumen. They are convoluted at their distal apertures (Fig. 16).

The eyes in the three cyclosalpas, *pinnata, chamissonis* and *dolichosoma-virgula*, show an interesting series of modifications. Figs. 3 and 4, Plate VII., show the character of the large eye in *C. pinnata.* It is roughly a horseshoe with the ends directed backward, and having an additional mass of optic cells placed in the curve of the horseshoe. This eye has been shown (by Metcalf) to be derived from a horseshoe-shaped eye, like that of the solitary salpa, whose free ends point forward. The position of the eye has been reversed by an actual tipping forward of the whole eye, the ends of the horseshoe remaining attached to the ganglion, while the curved part of the horseshoe swings forward through an arc of 180° (*cf.* Text-figs. 1 to 6). The horseshoe shape of the adult eye of the chain *C. pinnata* is therefore probably in a sense primitive, a reminder of the condition seen in the embryo, which corresponds to that in all the solitary salpas. For a time, however, in the development of the chain *C. pinnata* the young eye is undivided, there being no split between the lateral halves. This split, which appears later, is probably a reopening of the earlier space between the limbs of the horseshoe seen at a time when in the young embryo the eye had a form similar to that of the eye of the adult solitary salpa.

Metcalf has shown that the eye of the chain *Cyclosalpa chamissonis* is in a condition a little less developed than that of *C. pinnata.* It is in the form of a flat plate, with no split between its two halves (Pl. IX., Fig. 19), though there are two enlargements of its posterior portion, corresponding to the two limbs of the eye of *C. pinnata* and separated by a furrow which is in the position occupied by the split in the eye of *C. pinnata. C. chamissonis* has also an accessory mass of optic cells dorsal to the anterior part of the eye in the same position in which the similar body is seen in *C. pinnata* (compare Fig. 19, r''' with Fig. 18, p''' and e'''). The eye of *C. chamissonis* is either less developed or has reverted to a slightly simpler condition.

The eye of *Cyclosalpa dolichosoma-virgula* (Pl. VII., Fig. 1, and Pl. VIII., Fig. 5) is still more different from that of *C. pinnata.* It

is irregularly conical rather than flat and shows no sign of division into right and left limbs, approaching in form and structure the eye of the true *Salpæ*, for example *S. runcinata-fusiformis*.



Outline drawings of ganglia and eyes of salpa.

a. = anterior; *d.* = dorsal; *Gg.* = ganglion; *p.* = posterior; *v.* = ventral; *x.* indicates in each case the same region of the eye.

FIG. A. Dorsal view of ganglion and eye of a solitary salpa. The horseshoe-shaped eye is above the ganglion, with the ends of the horseshoe pointing forward.

FIG. B. The same seen from the right side.

FIG. C. Ganglion and eye of an immature chain *Cyclosalpa pinnata*. In an earlier condition this eye was horseshoe-shaped and lay horizontally on the dorsal surface of the ganglion, resemblimg Figs. A and B. It has now rotated forward and upward through an arc of about 90°. That surface of the eye which was dorsal when the eye was horizontal is now anterior.

FIG. D. The same eye and ganglion as those shown in Fig. C., but here seen from behind. The eye is in the form of a flat plate, the hollow of the horseshoe having become filled with cells.

FIG. E. The eye and ganglion of an adult, chain *Cyclosalpa pinnata*, seen from the right side. The eye has shifted 90° still further forward and is again horizontal, but with its former posterior portion now anterior. (Cf. Plate VII., Fig. 3.)

FIG. F. Dorsal view of the same eye and ganglion as those shown in Fig. E. The eye is seen to be split posteriorly into two limbs, being again horseshoe-shaped. (Cf. Plate VII., Fig. 4.)

The protuberance from the ganglion, which lies at the base of the large eye, is very similar to that seen in *C. pinnata* (*cf.* Figs. 5 and 18). In the eye of *C. dolichosoma-virgula* there is a group of cells which strongly suggests comparison with the accessory mass of optic cells in the curve of the horseshoe in the eye of the chain *C. pinnata* and with the similar, though less distinct mass of cells in *C. chamissonis*. This mass of peculiar spindle-shaped cells does not show in surface view, but is shown as it appears in section in Pl. VIII., Figs. 5 and 10, *q*. They are not developed as rod-cells, yet their shape, their position, their innervation, and their relation to the pigment cells seem to indicate that they are to be compared to the accessory portion of the eyes of the other *Cyclosalpæ*. Yet, in spite of the presence of this peculiar group of cells, the eye of *C. dolichosoma-virgula* resembles those of the true *Salpæ* more than it does the eyes of the other *Cyclosalpæ*. If the *Cyclosalpæ* are more primitive than the *Salpæ*, as many structural features seem to indicate, the study of the eye of *C. dolichosoma-virgula* would suggest a transitional stage from one group to the other.

Another resemblance between *Cyclosalpa dolichosoma-virgula* and the true *Salpæ* is seen in the fact that in the former species and in *Salpa runcinata-fusiformis* there is found above the ganglion a peculiar ectodermal invagination which opens dorsally by a relatively narrow mouth, and which probably serves as a protection for the ganglion and eye, no large optic chamber being present in either of these species.

The position of the large eye in the chain salpas is worth noting. In most species the eye projects upwards (*Salpa runcinata-fusiformis*, Fig. 20, Pl. IX.) or forward from the dorsal face of the ganglion (compare Fig. 5, Pl. VIII., which shows a median section of the ganglion and eye of *Cyclosalpa dolichosoma-virgula*). In *Salpa punctata* the eye projects slightly downward from the antero-dorsal surface of the ganglion (Fig. 12, Pl. IX.). In *Thalia democratica-mucronata* the eye projects downward and backward from the antero-ventral surface of the ganglion (Fig. 17, Pl. IX.). These conditions, and the manner in which in *Thalia* the ectoderm is drawn down in front of the ganglion, indicate that the whole ganglion with the eye has rotated forward and downward. Compare Figs. 5, 12 and 17, and note that in

Cyclosalpa dolichosoma-virgula the positions of these parts is the usual one ; in *Salpa punctata* the shifting has been slight, about 45 °, in *Thalia* the rotation is greatest, 180 ° or more. The position and arrangement of the nerves in *Thalia* confirms this interpretation.

Remembering the rotation that has occurred in *Salpa punctata*, it seems clear, on comparing Fig. 5, Pl. VIII., and Fig. 12, Pl. IX., that the group of rod-cells lying behind the origin of the optic nerve, in the dorsal part of the ganglion, in *S. punctata* corresponds to the postero-dorsal protuberance from the ganglion in *Cyclosalpa dolichosoma-virgula*, although in the latter species rod-cells are not found in this region. There is great diversity between species in the extent to which groups of rod-cells are developed in the periphery of the ganglion. A similar postero-dorsal protuberance containing no rod-cells is found in *Cyclosalpa pinnata* (Fig. 18, Pl. IX.).

LITERATURE CITED.

Göppert, E.

Untersuchungen über das Sehorgan der Salpen. Morph. Jahrbuch, Bd. 19, Heft 3.

Metcalf, M. M.

The Eyes and Sub-Neural Gland in Salpa. Mem. Biol. Lab. Johns Hopkins Univ., Vol. II., Part IV.

Explanation of Plates.

a, accessory mass of optic cells; *b*, small cells of latero-ventral outgrowths from ganglion; *b'*, large cells of latero-ventral outgrowths from ganglion; *bl*, blood sinus; *d*, duct of neural gland; *dp*, dorsal pigment cells of large eye; *dr*, dorsally-directed rod-cells of large eye; *e'''*, "accessory portion" of *Cyclosalpa pinnata* eye; *ec*, outline of ectodermal chamber above the ganglion; *ex*, dorsal group of rod-cells in ganglion of *Salpa runcinata-fusiformis* and *Salpa punctata;* in Fig. 17 it indicates a group of optic cells in *Thalia democratica-mucronata* which may be homologous with the cells marked *ex* in the *Salpæ* (cf. Figs. 12 and 20, Plate III.); *ey*, *ey'*, *ey''*, groups of rod-cells in peripheral cellular layer of ganglion of *Cyclosalpa dolichosoma-virgula;* *ez*, a group of optic cells in *Thalia democratica-mucronata* which is apparently homologous with one of the posterior limbs of the horseshoe-shaped eye of the chain form of *Cyclosalpa pinnata;* *g*, ganglion; *gc*, fibrous core of ganglion; *gz*, membrane surrounding ganglion; *h*, neural gland; *hz*, membrane separating gland wall from large cells of latero-ventral outgrowths; *i*, dorsal intermediate cells of large eye; *i'*, ventral intermediate cells of large eye; *l*, peripheral cellular layer of ganglion; *lp*, lateral pigment cells of large eye; *lr*, laterally-directed rod-cells of large eye; *n*, nerve; *nc*, nerve cells; *o*, opening of duct of neural gland into the pharynx; *oc*, optic chamber; *on*, optic nerve; *os*, optic ectodermal sheath; *oz*, optic membrane covering eye; *p'''*, pigment cells of "accessory portion" of *Cyclosalpa pinnata* eye; *pc*, pigment curtain in *Salpa punctata* eye; *pr*, postero-dorsal protuberance on ganglion of *Cyclosalpa dolichosoma-virgula*; *q*, group of spindle-shaped cells in mid-dorsal region of *Cyclosalpa dolichosoma-virgula* eye; *q'*, group of cells posterior to pigment curtain in *Salpa punctata* eye; *r'''*, group of rod-cells in eye of *Cyclosalpa chamissonis*; *sc*, supra-neural ectodermal chamber of *Salpa punctata*; *vl*, ventro-lateral outgrowth; *vp*, ventral pigment cells of large eye; *vr*, ventrally-directed rod-cells of large eye; *gw*, thickened portion of gland wall; *x*, nerve which arises from one of the ventro-lateral outgrowths; *y*, outline of optic chamber; *z*, limiting membrane of optic chamber.

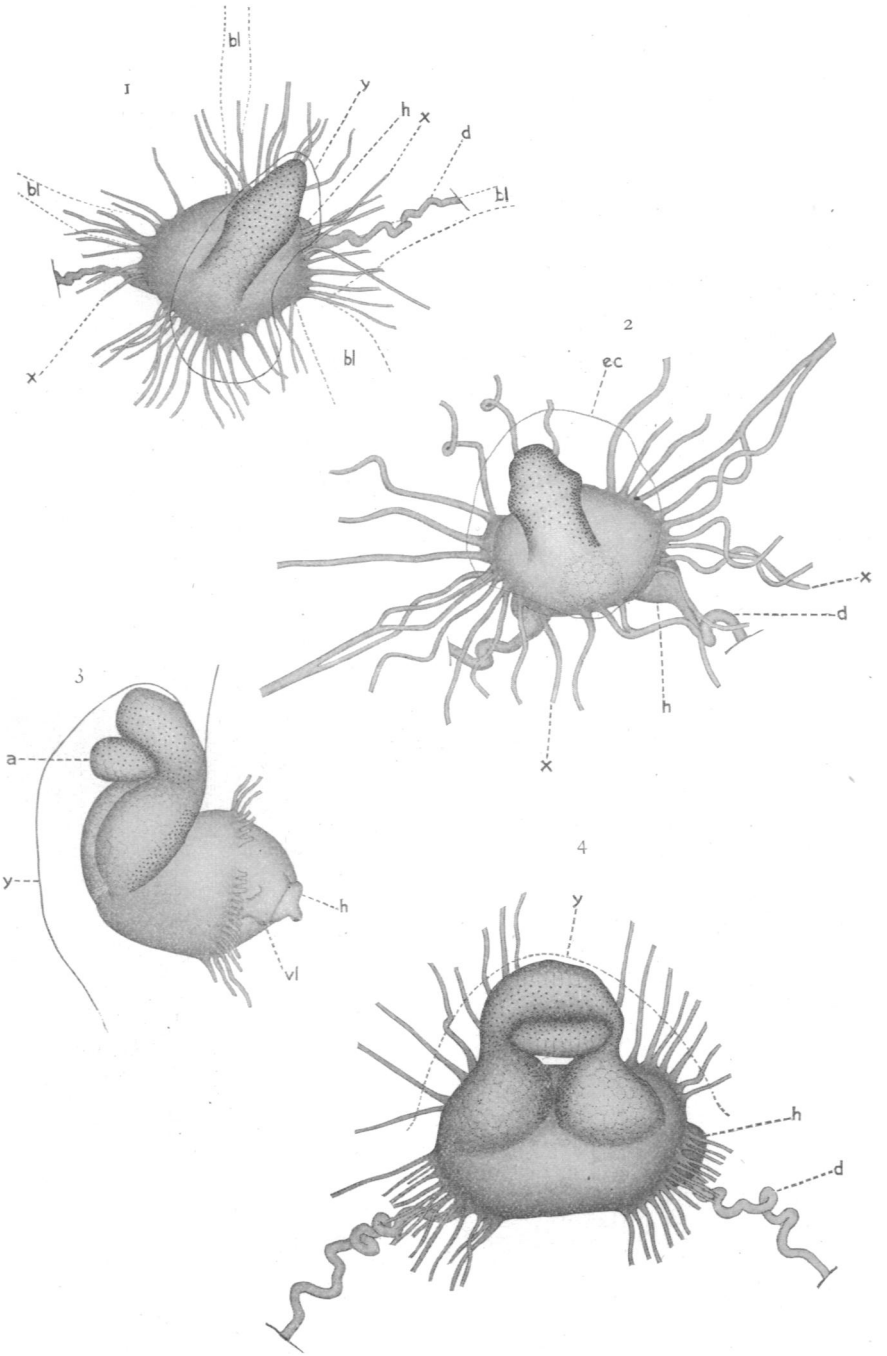
Explanation of Plate VII.

Fig. 1. Dorsal view of eye, ganglion and nerves of *Cyclosalpa dolichosoma-virgula* chain form, showing also neural glands and ducts. The pigment of the eye is represented by heavy stippling. The ends of the rod-cells when visible are indicated by faintly stippled outlines. The outlines of some of the blood sinuses are indicated by dotted lines. The extent of the optic chamber is indicated by a contour-line.

Fig. 2. Dorsal view of the eye, ganglion, nerves, glands and ducts of *Salpa punctata*. The pigment of the eye is represented by heavy stippling. The rod-cells in the dorsal part of the ganglion are indicated by faintly stippled outlines. The rod-cells of the posterior portion of the large eye lie below so thick a layer of nerve fibers that their outlines do not show.

Fig. 3. The eye, ganglion, nerves and gland of the chain form of *Cyclosalpa pinnata* seen from the right side. The heavy stippling indicates pigment. The faintly stippled outlines indicate the contours of the rod-cells. The contour-line indicates the extent of the optic chamber. (Copied from Metcalf.)

Fig. 4. Dorsal view of the same. (Copied from Metcalf.)


1
bl
y
h
x
d
bl
bl
x
bl
2
ec
x
d
h
x
3
a
y
h
vl
4
y
h
d

Explanation of Plate VIII.

Figs. 5–11. *Cyclosalpa dolichosoma-virgula*, chain form. Compare Fig. 1.

Fig. 5. Longitudinal vertical section of eye and ganglion, compounded from three oblique sections.

Fig. 6. Longitudinal section through the latero-ventral outgrowths from the ganglion and through one neural gland.

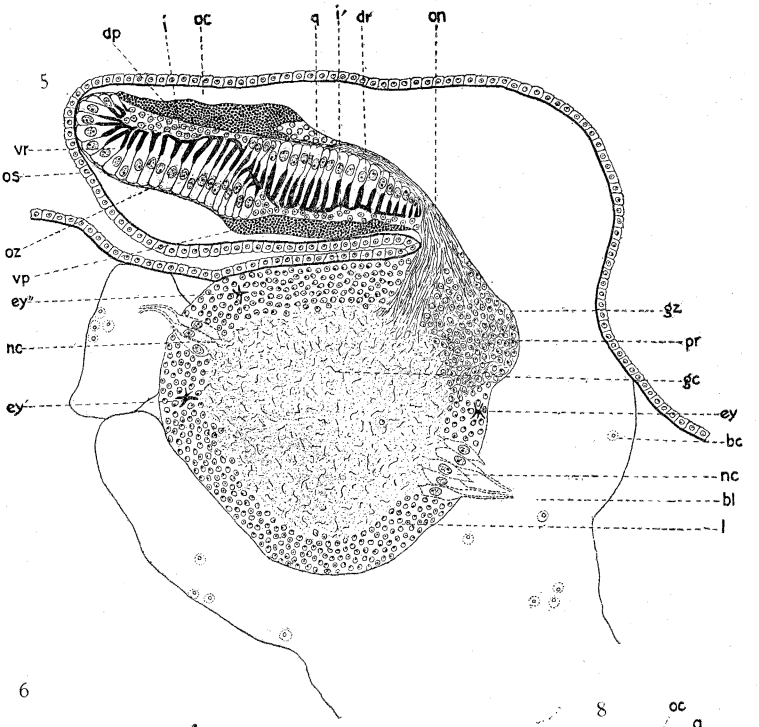
Fig. 7. Cross-section through the eye near the tip.

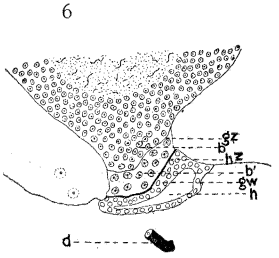
Fig. 8. Cross-section through middle of eye.

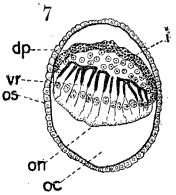
Fig. 9. Cross-section through eye near the base.

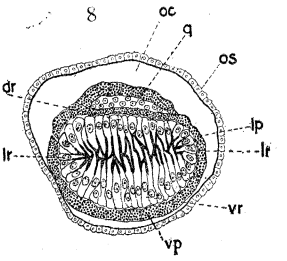
Fig. 10. Enlarged drawing of the section of the middle portion of the eye shown in Fig. 5, to show group of spindle-shaped cells, *q*.

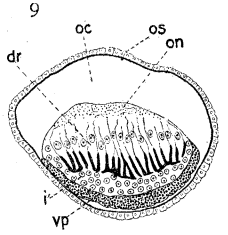
Fig. 11. Enlarged drawing of one of the groups of rod-cells in the peripheral cellular layer of the ganglion.

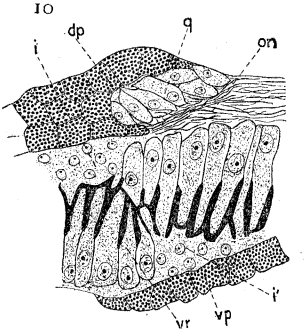

5
dp
oc
q
i'
dr
on
vr
os
oz
vp
ey"
nc
ey'
gz
pr
gc
ey
bc
nc
bl
l

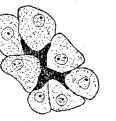

6
gz
b
hz
b'
gw
h
d


7
dp
i
vr
os
on
oc


8
oc
q
os
dr
lp
lr
lr
vr
vp


9
oc
os
dr
on
i'
vp


10
i
dp
q
on
i'
vr
vp


11

Explanation of Plate IX.

Figs. 12–16. *Salpa punctata*, chain form. Compare Fig. 2.

Fig. 12. Longitudinal vertical section of eye and ganglion.

Fig. 13. Cross-section through the eye near the tip.

Fig. 14. Cross-section through the middle of the eye.

Fig. 15. Cross-section through the eye near the base. In a section still further back the pigment would appear ventrally as well as laterally.

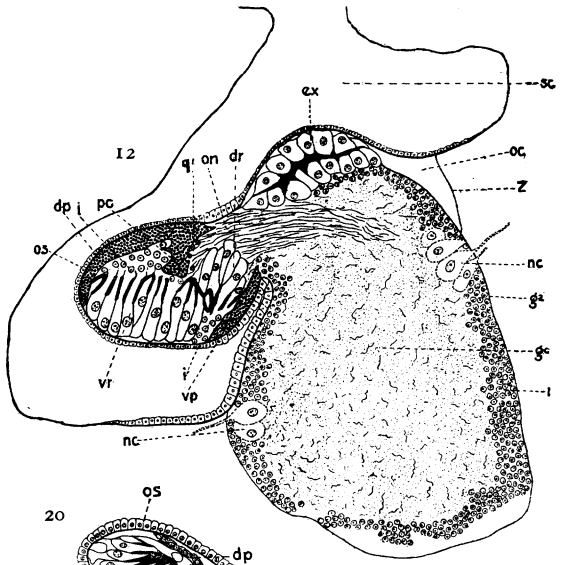
Fig. 16. Horizontal section through the distal end of the duct of one neural gland, showing convolutions at the aperture of the duct.

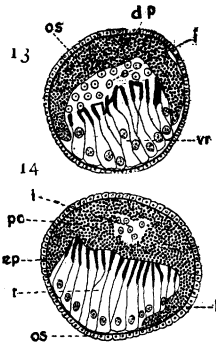
Fig. 17. Longitudinal vertical section of the eye and ganglion of *Thalia democratica-mucronata*, chain form (copied from Metcalf).

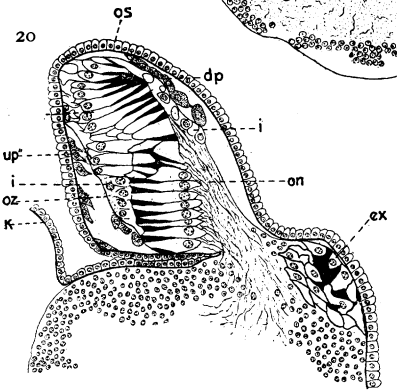
Fig. 18. Longitudinal vertical section of the eye and ganglion of *Cyclosalpa pinnata*, chain form (copied from Metcalf).

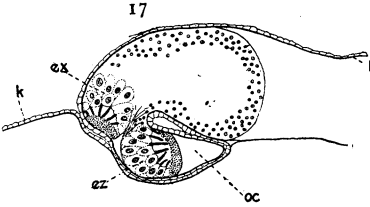
Fig. 19. Oblique (horizontal-cross) section through the middle of the eye of *Cyclosalpa chamissonis*, chain form (copied from Metcalf).

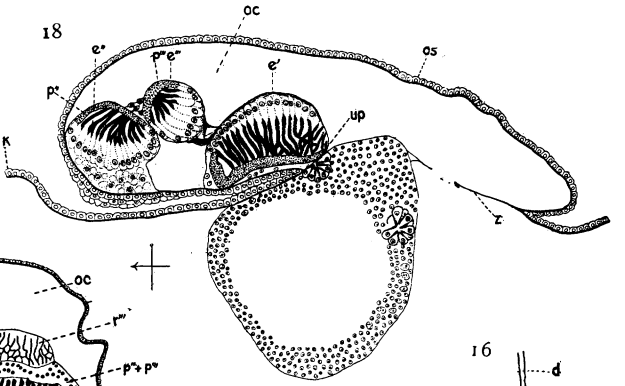
Fig. 20. Longitudinal vertical section of the eye and anterior part of the ganglion of *Salpa runcinata-fusiformis*, chain form (copied from Metcalf).

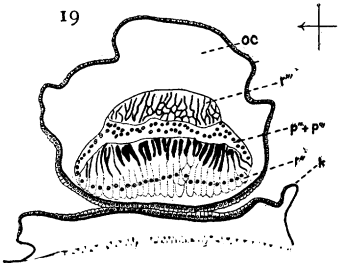

12
ex
sc
on
dr
oc
z
dp
i
pc
os
nc
g²
gc
vr
vp
l
nc

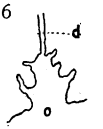

13
dp
os
f
vr
14
i
pc
ep
f
lp
os
15
lp
os
dv
lp
i


20
os
dp
i
up
i
on
oz
k
ex


17
ex
k
k
ez
oc


18
oc
e'
p''e''
e'
os
p'
up
k
z


19
oc
r'''
p'+p''
r'
k


16
d
o